The Time Dependence of Fundamental Constants and Planck Scale Physics

Frederick Rothwarf[1,2] and Sisir Roy[3,4]

[1] *Department of Physics, George Mason University, Fairfax, VA 22030 USA*

[2] *Magnetics Consultants, 11722 Indian Ridge Road, Reston, VA 20191,USA*

[3] *Center for Earth Observing and Space Research and School of Computational Sciences, George Mason University, Fairfax, VA 22030 USA*

[4] *Physics and Applied Mathematics Unit, Indian Statistical Institute, Calcutta, INDIA*

[2] e.mail: frothw@ieee.org

[3] e.mail: sroy@scs.gmu.edu

Abstract

A real aether model of the vacuum proposed by Allen Rothwarf(1) based upon a degenerate Fermion fluid, composed of polarizable particle-antiparticle pairs, leads to a big bang model of the universe where the velocity of light varies inversely with the square root of the cosmological time. Here this model is used to determine the time dependence of certain fundamental constants, i.e., permittivity $\epsilon(t)$ and permeability $\mu(t)$ of free space: the Gravitational constant $G(t)$; and the Planck units: length $l_p(t)$, time $t_p(t)$, and mass, m_p.

Keywords: Fundamental constants, Planck units, Polarizable vacuum, Zitterbewegung.

1 Introduction

An aether model of the universe has been proposed by Allen Rothwarf[1] based upon a degenerate Fermion fluid, composed of polarizable particle-antiparticle pairs in a negative energy state, relative to the null state or true vacuum. He proposed that the Fermion fluid was composed primarily of a degenerate electron-positron plasma. The model provides insight into a large number of physical and cosmological phenomena for which conventional theories have unsatisfactory or no answers. Among the various issues he treated: wave-particle duality; the nature of spin (a vortex in the aether); the derivation of Hubble's law; electric fields (polarization of the aether); Zitterbewegung (a bare particle orbiting within a vortex core); inflation and the big bang in cosmology; the Pauli exclusion principle (repulsion between parallel spin vortices); the nature of the photon (a region of rotating polarized aether propagating with a screw like motion) are few of them. A key assumption of this model is that the Fermi velocity, v_F, of the degenerate electron-positron plasma that dominates the aether is equal to the present speed of light c_0. One of many important consequences of this model is that the speed of light decreases with cosmological time according to the relationship

$$c(t) = c_0 \left(\frac{t_0}{t}\right)^{1/2} \tag{1}$$

where c_0 is the present speed of light and t_0 is the present age of the universe after the end of inflation. In this paper, this relationship is used to determine the time dependence of certain fundamental constants, namely, the permittivity $\epsilon(t)$ and permeability $\mu(t)$ of free space; the Gravitational constant $G(t)$; and the Planck length $l_p(t) \sim 10^{-35}$m, time $t_p(t) \sim 10^{-44}$ s, and mass, $m_p \sim 10^{-8}$kg. It should be

noted that some other models assuming a polarizable aether or vacuum have been proposed. These have been cited and discussed in detail by Rothwarf[(1)] and Puthoff[(2)]. However, none of these models derive a relationship for $c(t)$. Furthermore, the cited literature refers to two types of aether. We denote one by $\mathbf{A_{EM}}$ and the other $\mathbf{A_G}$. Van Flandern himself[(3)] and together with Vigier[(4)] made a clear distinction between these two type of aethers. The Rothwarf model deals with $\mathbf{A_{EM}}$, while the polarizable vacuum, proposed by Puthoff[(2)], concerns $\mathbf{A_G}$. The possible interaction of these two interpenetrating fluids will be discussed in a subsequent paper[(5)].

2 The Time Variation of Physical Constants

2.1 The Determination of $\epsilon(t)$ and $\mu(t)$

Recently Puthoff[(2)] has published a Polarizable-Vacuum (PV) approach to General Relativity (GR) in which the basic postulate is that the polarizability of the vacuum, in the vicinity of a mass, (or other mass-energy concentrations) differs from its asymptotic far-field value by virtue of vacuum polarization effects, induced by the presence of the mass. Thus, he proposed that for the vacuum itself

$$D = \epsilon E = K \epsilon_0 E \tag{2}$$

where K is the altered dielectric constant of the vacuum (assumed to be a function of position in his formulation), due to changes in vacuum polarizability (GR-induced).

In the present paper, K is considered as a function of cosmological time, $K(t)$. We consider that the expected polarizability of the vacuum (aether) will be changing as the

density of the aether decreases with the expansion of the universe. This is consistent with the assumption of this model which states that the number of electron-positron pairs in the universe remains constant after the end of the inflationary phase of the big bang.

We begin our analysis by considering the fine structure constant, α, that governs electromagnetic interactions, i.e.,

$$\alpha = \frac{e^2}{2\epsilon_o h c_0} \tag{3}$$

where, $c_0 = (\frac{1}{\mu_0 e_0})^{1/2}$ in the aether model, considered here. In the present case, e and h are taken as constants; c_0, ϵ_0, and μ_0 are the present values of the speed of light, the vacuum permittivity and the vacuum permeability, respectively. Taking into consideration that ϵ_0 is expected (with a time-varying aether polarizability) to change to $\epsilon(t) = K(t)\epsilon_0$, the fine structure constant α can be rewritten as,

$$\alpha = \frac{e^2}{2\epsilon(t) h c(t)} \tag{4}$$

or

$$\alpha = \frac{e^2}{2K(t)\epsilon_0 h c(t)} \tag{5}$$

There is reason to believe that α has not varied significantly with time since the end of inflation. From the observations of quasar absorption spectra , Webb et al.[6] showed that α was slightly lower in the past, with $\frac{\Delta\alpha}{\alpha} = -0.72 \pm 0.18 \times 10^{-5}$ for $0.5 < z < 3.5$. Analyzing geological constraints, imposed on a natural nuclear fission event at Oklo, Damour and Dyson[7] concluded that $\frac{\Delta\alpha}{\alpha}$ over the past 1.5 billion years has been $< 5.0 \times 10^{-17}\text{yr}^{-1}$. Therefore, with substantial compatibility,

one can substitute (1) into (5) to obtain $K(t)$ which is

$$K(t) = \left(\frac{t}{t_0}\right)^{1/2} \tag{6}$$

Then the permittivity is given by

$$\epsilon(t) = K(t)\epsilon_0 = \left(\frac{t}{t_0}\right)^{1/2} \epsilon_0 \tag{7}$$

Now rewriting the expression for c(t) as

$$c(t) = c_0 \left(\frac{t_0}{t}\right)^{1/2} = \left[\frac{1}{\mu(t)\epsilon(t)}\right]^{1/2}$$

and$c_0 = \left(\frac{1}{\mu_0\epsilon_0}\right)^{1/2}$, one can solve for $\mu(t)$ from (7) and (6) and obtain

$$\mu(t) = \mu_0 \left(\frac{t}{t_0}\right)^{1/2} \tag{8}$$

Thus, the Rothwarf aether model shows that $\epsilon(t)$ and $\mu(t)$ have the same functional dependence on cosmological time.

2.2 Time Dependence of Gravitational Constant

Puthoff[8] discussed gravity as a Zero-Point-Fluctuation (ZPF) force. To be more accurate, he developed in detail the approach, originally put forth by Sakharov[9], who proposed a model in which gravity is not a separately existing force, but rather an induced effect associated with ZPF of the vacuum, in much the same way as the Van der Waals and Casimir forces. Sakharov[9] conjectured that the Lagrange function of the gravitational field is generated by vacuum polarization effects due to fermions. Akama, et al.[10] developed this approach further and claimed that the generation of gravity is due to a collective excitation of fermion-antifermion pairs. Then Puthoff established a quantitative, point particle-ZPF model and showed that gravitational mass

and its associated gravitational effects, i.e., the inverse square law, can be derived in a fully self-consistent way from electromagnetic-ZPF-induced particle motion (Zitterbewegung). He denoted these particles, undergoing ZPF, as partons. This model relates the gravitational constant, G, to the cut-off frequency, ω_c as the broad-spectrum ZPF radiation fields, generated by the Zitterbewegung. To obtain quantitative agreement with the present value of G, i.e., G_0, Puthoff's model requires that (1) the cut-off frequency for the ZPF background to be of the order of the Planck frequency, ω_p; (2) the partons, undergoing ZPF, have masses of the order of the Planck mass, i.e., m_p; and (3) the vibrational amplitude be of the order of the Planck length, l_p. Using the usual definations, we write

$$l_p = \left(\frac{hG}{c^3}\right)^{1/2}, \quad t_p = \left(\frac{hG}{c^5}\right)^{1/2}, \quad \& \quad m_p = \left(\frac{hG}{c}\right)^{1/2} \tag{9}$$

According to Puthoff the equation for G follows as,

$$G = \frac{2\pi^2 c^5}{h\omega_c^2} \tag{10}$$

It is worth mentioning that Rothwarf[1] discussed in detail the Zitterbewegung of an electron of mass, m_e on the core of a vortex in the presence of an aether medium and showed that the ω_c calculated with the aether model, corresponds precisely with that obtained, taking into consideration the relativistic QM Dirac equation for a free particle which is

$$\omega_c = \frac{2\pi m_e c^2}{h} \tag{11}$$

At this point, we assume that the cutoff-frequency of Puthoff's partons, will have the same functional relationship as the electrons will have in (11), and that m_p will now

replace m_e to obtain ω_c for the partons, vibrating at the cores of vortices in the aether A_G. When (11) and (1) are substituted in (10) one obtains

$$G(t) = G_0 \left(\frac{t_0}{t}\right)^{1/2} \quad \text{where} \quad G_0 = \frac{\pi h {c_0}^2}{2m_p} \tag{12}$$

which indicates that $G(t)$ has the same dependence on time as does $c(t)$.

2.3 Time Dependence of Planck Units: l_p, t_p and m_p

The Planck units have been defined in (9), where their dependence on $c(t)$ implies that they may also vary with time. Substituting (1) and (12) into the expression of Planck length, l_p in (9), we get,

$$l_p(t) = l_{p0} \left(\frac{t}{t_0}\right)^{1/2} \quad \text{where} \quad l_{p0} = \left(\frac{hG_0}{c_0^3}\right)^{1/2} \tag{13}$$

showing that l_p has a time dependence which is the inverse of $c(t)$. In the same way, we can obtain the values for t_p as

$$t_p = t_{p0}(\frac{t}{t_0}) \quad \text{where} \quad t_{p0} = \left(\frac{hG_0}{c_0^5}\right)^{1/2} \tag{14}$$

This establishes the fact that t_p increases linearly with time. Finally, when we consider the expression for the Planck mass, m_p in (9), we find that it is just a constant and independent of time, since the time variations of $c(t)$ in the numerator and $G(t)$ in the denominator, cancel out each other.

3 Discussion

We have applied the Rothwarf model of the electron-positron aether, $\mathbf{A_{EM}}$, to evaluate the time dependence of several important physical cosnatnts. One of the major

consequences of this work is that the fractional time rate of change of $c(t)$ and $G(t)$ is calculated to be $-(\frac{1}{2t_0}) = -3.65 \times 10^{-11}\mathrm{yr}^{-1}$ by using $t_0 = 13.7 \times 10^9\mathrm{yr}$ from Webb et al.(6). Rothwarf(1) has suggested that a modified **LIGO** experiment might well be able to test this result. The future experiments with sufficient sensitivity will be useful to verify our various time dependent predictions as given in (1),(6),(8) and (12). It should be noted, however, that G_0 as defined in terms of m_p in (12) represents a tautology, since, m_p itself is defined in terms of G_0. Thus, G_0 is a measured rather than a derived quantity in this model.

As we mentioned in the *introduction*, several models of gravity(8−10) require a polarizable vacuum (aether), made up of fermions and their anti-matter counterparts. These particles, called partons(8) or gravitons(3,4), are assumed to have a mass equal to the Planck mass m_p and to constitute an aether, $\mathbf{A_G}$, that transmits gravitational forces at a speed c_G, which exceeds the speed of light c_0. Van Flandern and Vigier(4) have analyzed planetary and cosmological data to obtain a lower limit of $c_G < 2 \times 10^{10} c_0 = 6 \times 10^{18}\mathrm{m/s}$. $\mathbf{A_G}$ is assumed to obey the same Fermi-Dirac statistics that govern $\mathbf{A_{EM}}$, so that the same arguments which give $c(t)$ in (1) will yield the same functional dependence for $c_G(t)$ and will give the Zitterbewegung frequency form given in (11). It should be emphasized that the fermion-antifermion model used here to describe $\mathbf{A_{EM}}$ and $\mathbf{A_G}$ assume that Planck cosntant, the mass and charge of the electron and also the Planck mass do not vary with cosmological time. We are aware that other approaches have been constructed by several authors(11,12), which fix G and allow the Planck constant to vary with time. These are based on a conjecture of Calogero(13), who calculates Planck constant by using the arguments of stochastic mechanics and

by assuming that G is a constant. We believe that our present approach yields more consistent cosmological consequences that leads us to explore the interaction of the two aethers. The details of such an interaction will be given in a subsequent paper[5] which might shed new light in understanding the physics at the Planck scale.

Acknowledgements One of the authors (S.Roy) greatly acknowledges School of computational Sciences and Center for Earth Observing and Space Research, George Mason University, USA for their kind hospitality and funding for this work.

REFERENCES

1. A.Rothwarf , Physics Essays,**11**,444-466(1998).

2. H.E. Puthoff, Foundations of Physics,**32**,927-943(2002).

3. T.Van Flandern , Phys.Lett.,**A 250**,1-11 (1998).

4. T.Van Flandern and J.P. Vigier, Found. Phys.,**32**,1031-1068(2002).

5. F.Rothwarf and S.Roy (in preparation).

6. J.K. Webb, M.T. Murphy, V.V. Flambaum, V.A. Dzuba, J.D. Barrow, C.W. Churchill,J.X. Prochaska, and A.M. Wolfe, Phys. Rev. Lett.,**87**,091301(2001).

7. T. Damour and F. Dyson, Nucl. Phys.,**B480**,37(1996).

8. H.E. Puthoff, Phys. Rev.,**A39**,2333(1989).

9. A.D. Sakharov, Theor. Math. Phys.,**23**,435(1975).

10. K. Akama, Y. Chikashige, T. Matsuki, and H. Terazawa, Prog. Theor. Phys.,**60**,868(1978).

11. G.Gaeta, Int.J.Theort.Phys.,**39**,1339(2000).

12. I.I.Haranas , J.Theoretics,**4**,1(2002).

13. F.Calogero, Phys.Lett.,**A 228**,335-346(1997).